

## ORIGINAL ARTICLE

# Clinical Implementation of Cardiac Resynchronization Therapy—Regional Disparities across Selected ESC Member Countries

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**Background:** The present analysis aimed to estimate the penetration of cardiac resynchronization therapy (CRT) on the basis of the prevalence and incidence of eligible patients in selected European countries and in Israel.

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**Methods and Results:** The following countries were considered: Italy, Slovakia, Greece, Israel, Slovenia, Serbia, the Czech Republic, Poland, Romania, Hungary, Ukraine, and the Russian Federation. CRT penetration was defined as the number of patients treated with CRT (CRT patients) divided by the prevalence of patients eligible for CRT. The number of CRT patients was estimated as the sum of CRT implantations in the last 5 years, the European Heart Rhythm Association (EHRA) White Book being used as the source. The prevalence of CRT indications was derived from the literature by applying three epidemiologic models, a synthesis of which indicates that 10% of heart failure (HF) patients are candidates for CRT. HF prevalence was considered to range from 1% to 2% of the general population, resulting in an estimated range of prevalence of CRT indication between 1000 and 2000 patients per million inhabitants. Similarly, the annual incidence of CRT indication, representing the potential target population once CRT has fully penetrated, was estimated as between 100 and 200 individuals per million. The results showed the best CRT penetration in Italy (47–93%), while in some countries it was less than 5% (Romania, Russian Federation, and Ukraine).

**Conclusion:** CRT penetration differs markedly among the countries analyzed. The main barriers are the lack of reimbursement for the procedure and insufficient awareness of guidelines by the referring physicians.

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heart failure; cardiac resynchronization therapy; prevalence; incidence

Heart failure (HF) is a chronic progressive disease that results in substantial morbidity, mortality, and expenditure of health care resources.<sup>1,2</sup> Approximately 1–2% of the adult population in developed countries suffer from HF, with the prevalence rising to  $\geq 10\%$  among persons 70 years of age or older.<sup>3</sup> Clinical trials have established that cardiac resynchronization therapy (CRT) improves the clinical outcomes of patients with HF, reduced left ventricular ejection fraction (LVEF) and left ventricular conduction delays.<sup>2</sup> The European Society of Cardiology (ESC) Guidelines for the diagnosis and treatment of acute and chronic HF 2012<sup>4</sup> provide class I A recommendation for CRT treatment, with or without an implantable cardioverter defibrillator (ICD), in patients with symptomatic HF, sinus rhythm, QRS width  $\geq 120$  ms with left bundle branch block (LBBB) morphology and LVEF  $\leq 35\%$ . Although there has been a substantial increase in CRT implantation rates across Europe, marked differences among countries remain.<sup>5,6</sup> It is therefore likely that many patients who could potentially benefit from this therapy do not receive it. Since 2008, the European Heart Rhythm Association (EHRA) has published annual reports on CRT implantation rates in all represented countries.<sup>7</sup> However, the penetration of CRT in comparison with the number of eligible patients has not been studied in detail. The aim of the present analysis was to examine the penetration of CRT (with or without ICD) on the basis of the prevalence and incidence of CRT indications in a number of ESC member countries covering Central, Southern and Eastern Europe and Israel.

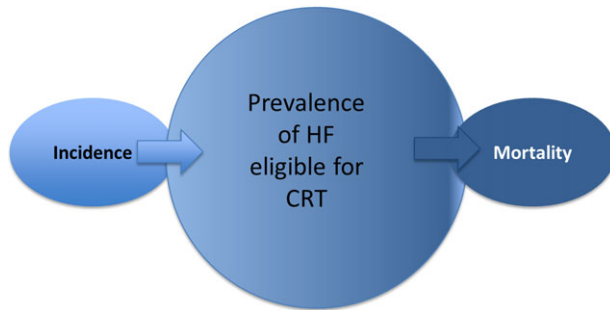
## METHODS

The following countries were considered in the analysis: Italy, Slovakia, Greece, Israel, Slovenia, Serbia, the Czech Republic, Poland, Romania, Hungary, Ukraine, and the Russian Federation. Each country was represented by a cardiologist, who actively contributed to the project.

CRT penetration was defined as the number of patients treated with CRT divided by the number of patients that, on the basis of ESC Guidelines class I A recommendation, should receive CRT; that is, the number of patients with a CRT implanted (CRT patients) in relation to the prevalence of CRT indications.

Assuming that the mean duration of recent CRT devices is 5 years,<sup>8</sup> the number of CRT patients was conservatively estimated as the cumulative number of CRT implantations over 5 years (from 2007 to 2011), including replacements; this approximation minimizes the number of patients counted twice. Both CRT-P (without ICD function) and CRT-D (with ICD function) were considered. The sources of data used for the analysis were the annual EHRA White Book reports.<sup>9</sup> All implantation rates were therefore cross-validated by the country coordinator.

The prevalence of CRT indication was derived from the literature; for simplicity, this was assumed to be constant over a period of a few years. This hypothesis is plausible, in that: (1) in the short term (5 years), HF prevalence is fairly stable;<sup>10</sup> (2) the ratio between the incidence and prevalence of CRT indication is roughly 1:10, which is similar to the ratio between the incidence and prevalence of



**Figure 1.** Simplified hypothesis in which prevalence of CRT indication is constant, since the mortality rate is compensated by the incidence of new eligible subjects.

HF, as reported below; (3) as the annual mortality rate in CRT-indicated patients is about 10%,<sup>11</sup> it approximately balances the incidence of new patients eligible for CRT. Figure 1 shows the simplified hypothesis, in which the prevalence of CRT indication is constant.

In order to estimate how many HF patients are indicated for CRT, three models were developed and compared:

- Model 1 (based on a report from the Italian Network on Congestive Heart Failure published by Baldasseroni et al.<sup>12</sup>): patients with Sinus Rhythm, LBBB, and LVEF < 30% represent 10.8% of HF patients.
- Model 2 (based on a paper by Shenkman et al.<sup>13</sup>): among patients with HF, those with QRS duration  $\geq 120$  ms and systolic dysfunction defined as LVEF < 45% account for about 14.1%.
- Model 3 (based on a report from the National Registry to Advance Heart Health (ADVANCENT) published by El-Chami et al.<sup>14</sup> and on data from the EuroHeart Survey<sup>15</sup>): 28.9% of systolic (LVEF  $\leq 40\%$ ) HF patients have sinus rhythm and QRS  $\geq 120$  ms,<sup>14</sup> and, since systolic HF patients represent 36% of all HF patients,<sup>15</sup> CRT indication—defined as LVEF  $\leq 40\%$ , sinus rhythm and QRS  $\geq 120$  ms—is present in about 10.4% of HF patients.

The consensus that emerges from the three models is that about 10% of patients with HF are indicated for CRT on the basis of current class I A guidelines.

Thus, considering that 1–2% of the general population is affected by HF,<sup>3</sup> the prevalence of CRT indication in the general population is about

0.1–0.2%, which means 1000–2000 individuals per million population. This range can be defined as the full CRT penetration range.

Finally, calculations were made for the individual participating countries. The demographics of each country were taken from The EHRA White Book.<sup>9</sup> The estimated number of CRT patients in each country was normalized per million inhabitants, that is, calculated as the sum of the last 5 years implantation rates, each normalized for the current country population. For each country, the number of CRT patients was compared with the full CRT penetration range, and CRT penetration was estimated.

In the field of implantable devices, once full penetration has been reached, that is, all indicated patients have received implants, the potential target for the therapy becomes equal to the annual incidence rate of indication. Thus, the incidence represents the real number of patients to treat every year.

The HF incidence values reported in the literature range from 0.13% to 1.44% in the general population.<sup>3,16–18</sup> For simplicity, we estimated HF incidence in a range of 0.1–0.2%, as reported above. Thus, the annual incidence of CRT indication was estimated in a range of 100–200 individuals per million. For each country, the number of patients who underwent implantation in the year 2011 (normalized for resident population) was compared with the range of incidence of CRT indication.

Provided the prevalence of eligible patients with HF is completely covered by CRT implants, the annual CRT implantation rate should fall into that range. This means that approximately all new patients indicated for CRT receive the therapy, which could be regarded as an ideal condition. When the penetration of CRT is partial, that range represents a minimum target. Achieving this target means that all newly eligible subjects, and possibly a portion of the remaining HF patients, will receive treatment.

## RESULTS

Demographic and CRT implantation data in the various countries from 2007 to 2011 are shown in Table 1. Absolute and normalized EHRA White Book implantation data<sup>9</sup> are reported. The last column displays normalized implantation data validated by the country's investigator, which were

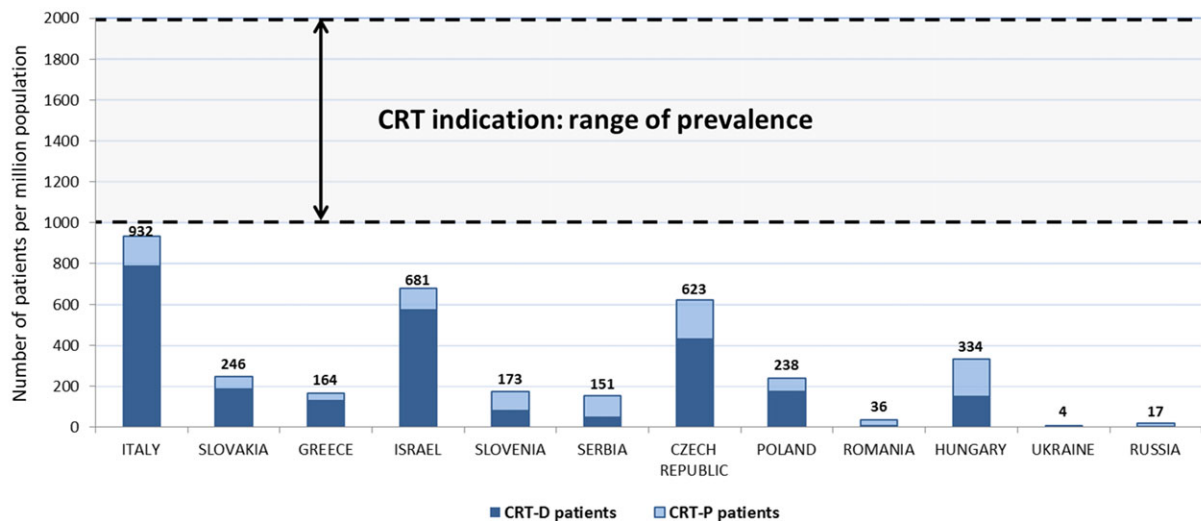
**Table 1.** Population and Annual CRT Implant Rates Normalized per Million Inhabitants of Each Country

Country	Demographics			EHRA White Book Implant Data			Normalized EHRA White Book Data			Normalized Validated Implantation Data		
	Year	Population	CRT-P	CRT-D	CRT	CRT-P	CRT-D	CRT	CRT-P	CRT-D	CRT	
Italy	2007	58,147,733	1537	8200	9737	26	141	167	26	141	167	
	2008	58,145,321	1500	9500	11,000	26	163	189	26	163	189	
	2009	58,145,321	1550	8800	10,350	27	151	178	27	151	178	
	2010	60,748,965	1800	10,000	11,800	30	165	194	30	165	194	
	2011	61,016,804	2000	10,380	12,380	33	170	203	33	170	203	
Slovakia	2007	5,402,273	30	81	111	6	15	21	6	15	21	
	2008	5,455,407	41	164	205	8	30	38	8	30	38	
	2009	5,460,862	72	221	293	13	40	54	13	40	54	
	2010	5,470,306	89	317	406	16	58	74	16	58	74	
	2011	5,477,038	78	251	329	14	46	60	14	46	60	
Greece	2007	10,964,020	85	238	323	8	22	29	7	16	23	
	2008	10,722,816	90	272	362	8	25	34	7	22	29	
	2009	10,733,539	386	429	815	36	40	76	7	29	36	
	2010	10,749,943	48	323	371	4	30	35	5	34	39	
	2011	10,760,136	32	364	396	3	34	37	5	32	37	
Israel	2007	7,112,359	79	489	568	11	69	80	11	69	80	
	2008	7,112,359	123	699	822	17	98	116	17	98	116	
	2009	7,233,269	154	838	992	21	116	137	21	116	137	
	2010	7,353,985	105	720	825	14	98	112	25	142	167	
	2011	7,473,052	100	527	627	13	71	84	27	154	181	
Slovenia	2007	2,009,245	39	2	41	19	1	20	19	1	20	
	2008	2,007,711	37	19	56	18	9	28	18	9	28	
	2009	2,005,703	36	31	67	18	15	33	18	15	33	
	2010	2,003,136	36	57	93	18	28	46	18	28	46	
	2011	2,000,092	35	55	90	17	27	45	17	27	45	
Serbia	2007	7,600,000	110	95	205	14	13	27	14	13	27	
	2008	7,413,882	158	69	227	21	9	31	21	9	31	
	2009	7,376,813	173	86	259	23	12	35	23	12	35	
	2010	7,344,847	73	64	137	10	9	19	10	9	19	
	2011	7,310,555	226	67	293	31	9	40	31	9	40	
Czech Republic	2007	10,391,130	313	608	921	30	59	89	30	59	89	
	2008	10,220,911	492	669	1,161	48	65	114	48	65	114	
	2009	10,210,690	551	1,033	1,584	54	101	155	54	101	155	
	2010	10,201,707	301	947	1,248	30	93	122	30	93	122	
	2011	10,190,213	289	1,171	1,460	28	115	143	28	115	143	
Poland	2007	38,518,241	440	140	580	11	4	15	11	4	15	
	2008	38,500,696	517	821	1,338	13	21	35	13	21	35	
	2009	38,500,696	606	1,741	2,347	16	45	61	16	45	61	
	2010	38,463,689	431	1,913	2,344	11	50	61	11	50	61	
	2011	38,441,588	387	2,152	2,539	10	56	66	10	56	66	

(Continued)

Table 1. Continued

Country	Demographics		EHRA White Book Implant Data			Normalized EHRA White Book Data			Normalized Validated Implantation Data		
	Year	Population	CRT-P	CRT-D	CRT	CRT-P	CRT-D	CRT	CRT-P	CRT-D	CRT
Romania	2007	22,246,862	89	34	123	4	2	6	4	2	6
	2008	22,246,862	75	24	99	3	1	4	3	1	4
	2009	22,224,615	100	40	140	4	2	6	4	2	6
	2010	21,959,278	171	42	213	8	2	10	8	2	10
	2011	21,904,551	159	61	220	7	3	10	7	3	10
Hungary	2007	9,956,108	275	218	493	28	22	50	28	22	50
	2008	9,930,915	304	217	521	31	22	52	31	22	52
	2009	9,901,122	389	281	670	39	28	68	39	28	68
	2010	9,992,339	396	436	832	40	44	83	40	44	83
	2011	9,976,062	454	352	806	46	35	81	46	35	81
Ukraine	2007	NA	NA	NA	NA	NA	NA	NA	0	0	0
	2008	NA	NA	NA	NA	NA	NA	NA	1	0	1
	2009	NA	NA	NA	NA	NA	NA	NA	1	0	1
	2010	45,415,596	45	1	46	1	0	1	1	0	1
	2011	45,134,707	49	6	55	1	0	1	1	0	1
Russian Federation	2007	140,702,094	166	60	226	1	0	2	1	0	2
	2008	140,702,094	322	123	445	2	1	3	2	1	3
	2009	139,998,584	346	116	462	2	1	3	2	1	3
	2010	139,390,205	317	149	466	2	1	3	2	1	3
	2011	138,739,892	365	428	793	3	3	6	3	3	6



**Figure 2.** Estimate of patients already treated with CRT in each country compared with the possible range of patients indicated for therapy, both normalized per million population (range depending on the HF prevalence range).

used to estimate CRT penetration. Figure 2 shows the numbers of patients in whom CRT-P and CRT-D devices were implanted from 2007 to 2011 in each country. The range of CRT indication prevalence represents the estimated range of subjects that should be treated, according to the guidelines. For comparison between countries, both data are normalized per million inhabitants. The estimated CRT penetration in each country is shown in Figure 3. The range is calculated on the basis of HF prevalence, which is between 1% and 2% of the general population.

Figure 4 shows the number of patients treated with CRT in each country from 2007 to 2011, normalized per million population, compared with the range of CRT indication incidence; the latter represents the number of new patients annually eligible for CRT and is also normalized per million inhabitants (range depending on the HF incidence range, estimated at 0.1–0.2% of the general population).

Italy is the country where CRT has the highest penetration: from 47% to 93% of patients indicated already have a device implanted. On the basis of the simplified model adopted, this means that, in the coming years, the number of CRT implantations should reach a value equal to the CRT indication incidence, which is estimated to be in the range of 100–200 implantations per million population.

Israel and the Czech Republic also display a good degree of therapy penetration, ranging from 34%

to 68% and from 31% to 62%, respectively. If maintained, the trend in CRT implantations seen in both countries in recent years will probably lead to greater penetration of the therapy in the near future.

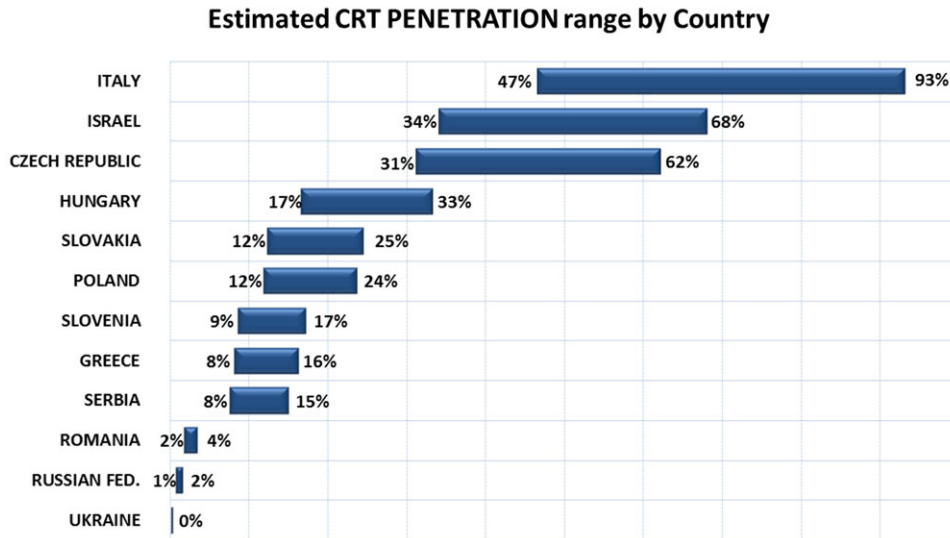
CRT penetration is still only partial in Hungary, where less than one of three indicated patients is treated. The figures are even lower in Slovakia and Poland, where only one of four receives the therapy. As the implantation rate in these countries is still low, CRT penetration will probably slowly improve in the near future.

In Slovenia, Greece, and Serbia, more than 80% of indicated patients are still not treated, and CRT adoption in recent years has also been very low.

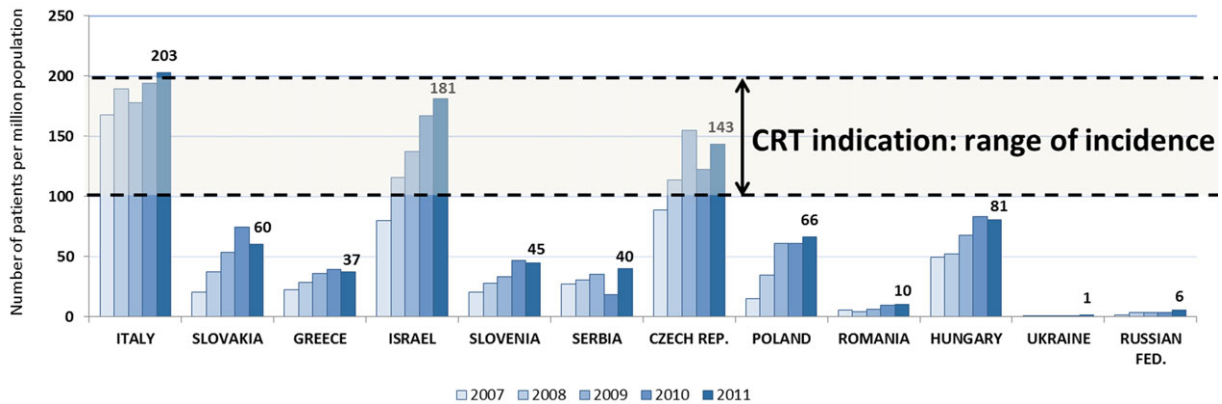
In Romania, the Russian Federation and Ukraine, CRT penetration is very poor, since less than 5% of patients that could benefit from the therapy are currently treated, and implantation rates are negligible.

The number of CRT-D devices as a percentage of total CRT implants is seen to have varied year by year in the different countries, as shown in Figure 5. In Italy and Israel, the proportion of CRT-D devices exceeds 80%, and has remained stable over the last 5 years. Slovakia, Greece, the Czech Republic, and Poland currently adopt CRT-D in more than 75% of cases, with the last two countries showing an increasing trend year by year. In Slovenia, CRT-D devices are increasing and currently account for about 60% of all CRT implants. In the Russian Federation, Hungary,





**Figure 3.** Estimated CRT penetration range in each country, represented as a range depending on the HF prevalence range.



**Figure 4.** Number of patients treated with CRT in each country from 2007 to 2011, compared with the range of CRT indication incidence, which represents the number of new patients annually eligible for CRT; both are normalized per million inhabitants (range depending on the HF incidence range).

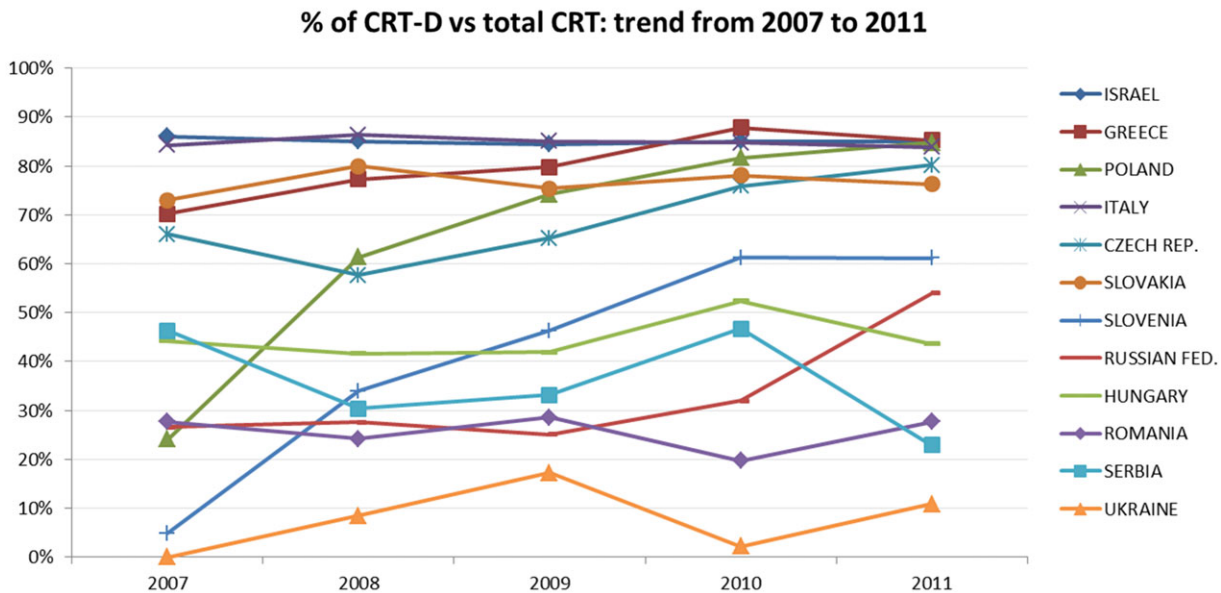
Romania, Serbia, and Ukraine, CRT-P devices are mainly used.

The main barriers to CRT penetration—as identified by the physicians representing each country—are summarized in Table 2.

## DISCUSSION

In the present study, we estimated the potential population eligible for CRT on the basis of HF epidemiology and, for the first time, we evaluated the penetration of CRT in terms of prevalence and incidence in different countries.

According to current ESC guidelines, CRT is fully recognized as having a class I indication, level of evidence A, for patients with symptomatic HF, LVEF  $\leq 35\%$ , sinus rhythm, and cardiac dyssynchrony, which is currently defined as QRS duration  $\geq 120$  ms. The potential CRT target has been estimated by Linde et al.,<sup>19</sup> who concluded that approximately 0.1% of the adult population should receive a CRT device. This percentage is consistent with our estimate of CRT indication prevalence. However, our study is the first to estimate CRT penetration, defined as the number of patients with a device already implanted as a proportion of the eligible population. Furthermore,



**Figure 5.** CRT-D devices as a percentage of total CRT implants in each country from 2007 to 2011.

considering that, once CRT has fully penetrated, the potential target for the therapy is equal to the annual incidence of CRT indication, we also estimated the incidence of CRT indication, defined as the annual number of new patients eligible for CRT, and compared this with annual implantation rates. This number is extremely important since it approximately represents the annual number of patients that we will be called to treat in the years to come. Finally, this analysis showed that, while CRT is universally accepted as a therapy for HF, there are significant differences in terms of penetration among the various countries considered.

### FACTORS AFFECTING DIFFERENCES IN CRT PENETRATION AND OPPORTUNITIES TO PROMOTE CRT ADOPTION

There are many reasons for the disparities in CRT penetration observed in different countries. Reimbursement by the national health care system for CRT device implantation seems to be an essential requirement for adequate adoption of the therapy; in countries where the cost of the procedure is not reimbursed or is only partially reimbursed, CRT penetration is very low and the

use of CRT-P devices is predominant. The issue of the cost-effectiveness of CRT has been addressed in several papers.<sup>20,21</sup> CRT-P appears to be a highly cost-effective addition to medical therapy in eligible patients, while CRT-D is cost-effective when life expectancy at the time of implantation is reasonable. Indeed, CRT has been shown to be cost-effective even in the ninth decade.<sup>21</sup> However, the problem is that cost-effectiveness analysis is difficult to transfer from one country to another, especially when the costs of labor, drugs, and medical devices vary significantly. Therefore, it is important to obtain country-specific data, since such data could convince governments to allocate health resources differently and/or prompt local health care insurers to reimburse CRT.

Another important factor in the adequate adoption of CRT is the availability of qualified personnel and the equipment required for successful implantation (C arm with the possibility of cine-loop acquisition, etc.). In some countries, the training of specialists remains a substantial issue. Training fellowships granted by the EHRA and/or organized directly by industry may help in this direction.

The adoption of CRT also depends on the awareness of physicians and patients. It is therefore of the utmost importance to "educate" referring physicians and to establish referral pathways. Campaigns to raise public awareness of CRT are another important component of this process.



**Table 2.** Considerations and Main Barriers to Therapy Adoption in Each Countries

Country	Considerations on CRT Adoption and Main Barriers to Therapy Penetration
Italy	Early adoption of CRT, currently well penetrated, thanks to: reimbursement covered by the national health care system, very high number of implanting centers (approximately 350), training activities, good cooperation with referral physicians, and early adoption of “gray zone” indications, such as atrial fibrillation.
Israel	Good penetration of CRT and strict adherence to implantation guidelines, assisted by recording of patients’ data in the Israeli ICD Registry, which is highly encouraged and covers almost 100% of high-power device implantations. Lack of specific reimbursement for high-power device implantation procedures to public hospitals is a disincentive to investment in personnel, equipment, and more electrophysiology laboratories.
Czech Republic	Despite limited financial resources, CRT has good penetration. Insurance companies control center accreditation for CRT (currently 19, two of which for CRT-P only) and verify, through specific registries, that every implantation complies with guidelines. Important role of education and training activities for implanters and clinical cardiologists and “Hub and spoke” model facilitate good referral of patients.
Hungary	The main obstacle to CRT penetration is that reimbursement is limited. To increase CRT penetration, the country is intentionally favoring the implantation CRT-P over CRT-D devices.
Slovakia	The main barriers to a wider adoption of CRT are limited financial resources and reimbursement policies. Another obstacle is the low awareness of guidelines among physicians working in medical departments in general hospitals, and the resulting insufficient referral to the four centers implanting CRT.
Poland	CRT penetration is severely limited by the budget allocated by the government to the implanting centers.
Slovenia	One of the main barriers is the lack of operators, since before 2005 device implantation was done by surgeons. Other obstacles are limited financial resources and low awareness of guidelines.
Greece	The main barriers to the penetration of CRT are lack of operators and trained personnel, low awareness of guidelines and, recently, considerable reduction of hospital budgets and, consequently, the limitation of implantations.
Serbia	The economic situation and consequent limited financial resources are the main reasons for the predominance of CRT-P. The strategy of the national working group for pacemaker therapy is to increase CRT-P therapy over CRT-D for better penetration. Awareness of guidelines is good owing to informational and educational campaigns.
Romania	The small number of devices provided by the national health care system means that CRT penetration is negligible. The overwhelming majority of CRT-D devices are paid for by patients, which also explains the predominance of CRT-P.
Russian Federation	CRT penetration is very poor. The main barriers are the lack of reimbursement: devices allocated by the national health care system are few; as patients often pay for the procedure personally, they prefer CRT-P for economic reasons.
Ukraine	CRT penetration and current implantation rates are negligible. Financial resources allocated to supplying devices are scant and implanting physicians lack specific competence.

## STUDY LIMITATIONS

The main limitation of the present study is that estimates of CRT penetration and of the prevalence and incidence of CRT indication are expressed as a wide range. This is due to the fact that both the prevalence and the incidence of HF are reported as wide ranges in epidemiologic studies. Since the prevalence of HF ranges from 1% to 2%, the estimated penetration of the therapy ranges from one percentage value to another which is twice as high; although this does not affect comparisons

among countries, the accuracy of the estimated CRT penetration in any single country is low. Once further epidemiologic studies have better determined the value of HF prevalence, the present analysis will be able to provide a more accurate estimate of CRT penetration.

Another limitation of the present analysis is that we used rough HF prevalence and incidence values, which were not adjusted for age. Thus, comparisons among countries considered the same range of prevalence and incidence of CRT indication in all cases. Since HF is highly correlated

with age,<sup>3</sup> the age distribution of the population will presumably influence the estimated range CRT indication in terms of prevalence and incidence, and consequently the estimate of CRT penetration. For example, 26% of the Italian population is older than 60 years, while in the Russian Federation the figure is 18%.<sup>22</sup> A further analysis should consider the epidemiology of HF adjusted for age, in order to refine estimates of CRT penetration and better compare different geographic areas.

## CONCLUSIONS

CRT penetration differs markedly among the countries analyzed. The main obstacles to patient recruitment are cultural and economic; cultural barriers are related to the awareness, dissemination, and implementation of guidelines, while economic barriers are mainly related to the lack of reimbursement for the procedure in several countries.

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